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BYTE

the small systems journal

Build a Light Pen

What's Inside an LSI-11?

Using Memory Address Space

Golf Handicapping By Computer

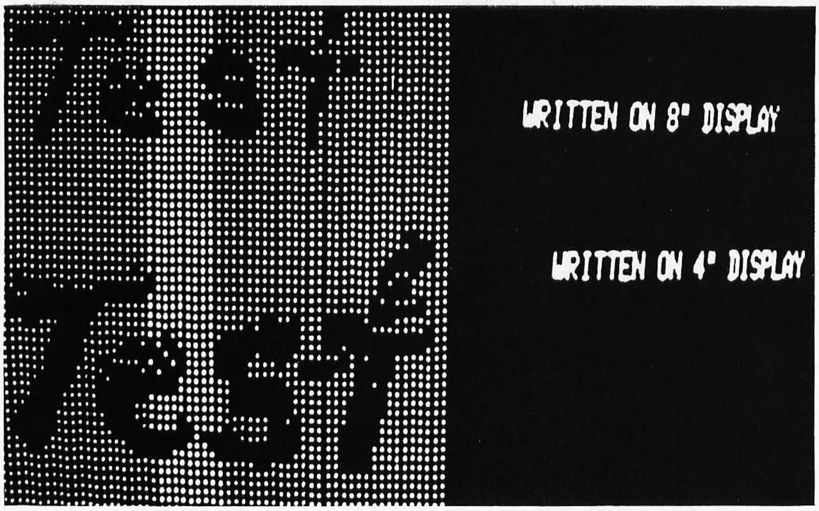


Photo 1: The ease of removing just one dot from a full field display depends upon the display size. The author's X-Y display has an adjustable size control which was used in preparing this picture.

Let There Be Light Pens

Sumner S. Loomis
Loomis Laboratories
Route 1 Box 131A
Prairie Point MS 39353

With only a few components and a few hours of construction you can add a versatile light pen to the oscilloscope graphics interface which has been described in the October 1975 issue of BYTE, page 70 ff.

By holding the light pen to the face of the cathode ray tube (CRT), a point may be added or removed. This eliminates the awkward and time consuming effort required when using a program or manual switches to change the dots on the screen.

The resolution and capability of the light pen are dependent on two characteristics of the CRT. The brightness and the size of the display tube will determine how easily you may add or remove one dot. An idea of the effect of display size may be had from photo 1. The word Test was written twice on a 12 inch (30.5 cm) black and white TV picture tube configured as an XY display like an oscilloscope. The top word was written with the display adjusted to an 8 inch (20.3 cm) size, and the lower word was written with a 4 inch (10.2 cm) display. Each letter was written with only one stroke of the light pen without touch up or corrections. With some practice, and possibly several passes, one dot may be added or removed if the display measures 8 inches (20.3 cm) or more. Further improvements to the pen are required with smaller display tubes. An advanced circuit that greatly improves the capability of the pen with small displays is also described in this article.

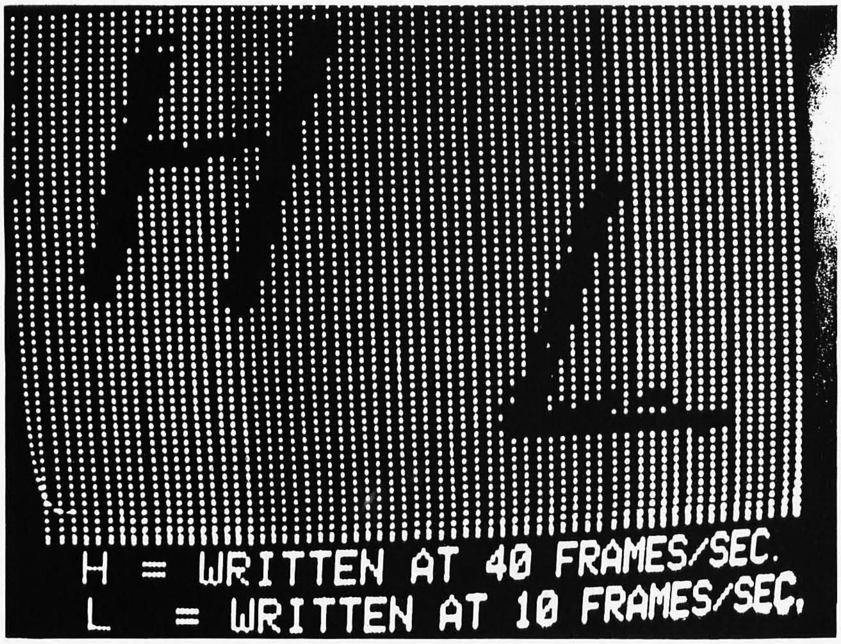


Photo 2: The light pen can be used in an "erase" mode by filling the screen with "on" dots then selectively removing dots with the light pen. The titles added to this picture (and all the pictures in this article) were created with a separate character generator which is not described.

The light pen can erase or draw depending on the setting of a switch. Examples of the two actions may be seen in photos 2 and 3. If the oscilloscope interface is adjusted for a high repetition rate, some smearing or carry over into the neighboring dot positions occurs. The author's system has a front panel control permitting ten repetition rates. A small improvement in resolution can be noted at the lower writing rates, as shown in photo 2. A frame consists of 64 by 64 dots.

Theory of Operation

The light pen operates on the principle that brightness is quite intense during the actual interval that a particular dot is being written by the CRT's electron beam. Although phosphor will continue to emit light for some time, the brightness decays in an exponential manner after the writing beam has moved on to the next dot.

Figure 1 illustrates the simple light pen circuit. With proper adjustment of the sensitivity control (and possibly the brightness control), the photocell in the tip of the light pen will sense the moment in time when a dot is written at the particular location of the light pen. At this instant, the photocell will conduct, biasing the PNP transistor which causes a short pulse to be conducted through capacitor C1 to the base of the NPN transistor Q2. If the pulse is greater than .6 V, this transistor will be driven into saturation, and the light pen output will fall to .3 V. This output line is the connected to pin 5 of the oscilloscope graphics unit which writes a 1 or a 0 bit (dot or no dot) at precisely the instant that the dot position touched by the pen was addressed.

The above procedure works quite well if the dot to be changed is illuminated at the time. With proper adjustment of the sensitivity control, we can usually use an illuminated dot just above the point of action (it must precede the dot in scan sequence) to create a new dot in the next space. This action of extending a line can be quite useful for drawing bar graphs on the CRT. This mode of entry is possible because screen persistence allows the light pulse to be carried over into two or three subsequent dot positions depending on the frame speed.

How can the photocell sense the dot's position if there is not any illumination to trigger it? This is accomplished by the flood circuit which is shown in figure 2. This circuit overrides the normal Z-axis control and floods the screen with light by feeding a logical one signal to the Z axis of the display unit. With this arrangement the pen is placed at the required dot position, the footswitch is actuated to flood the screen with light, and the photocell is energized when the

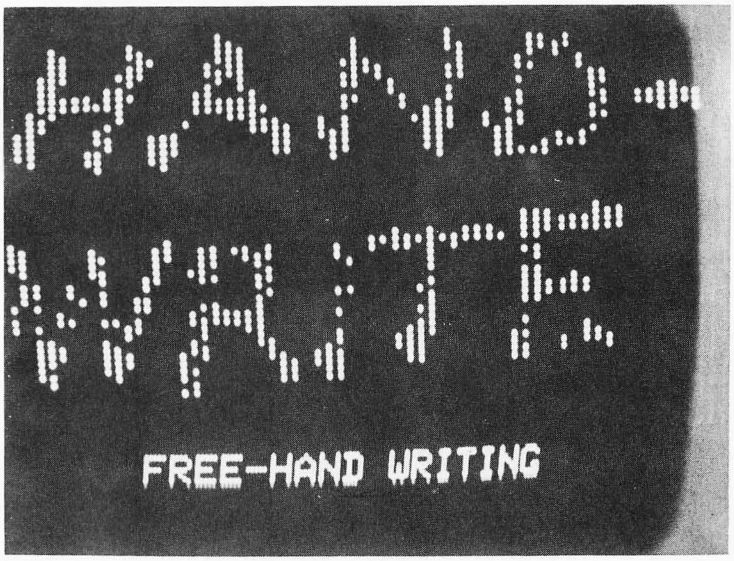
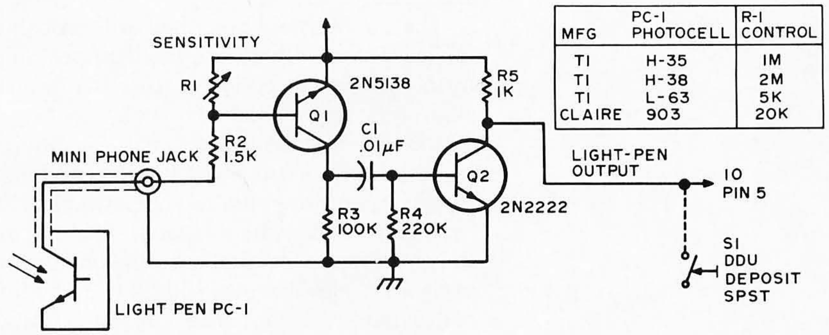


Photo 3: The light pen can be used in an "enhance" mode by using a footswitch control to flood the screen momentarily when the light pen is in position.



MFG	PC-1 PHOTOCELL	R-1 CONTROL
TI	H-35	1M
TI	H-38	2M
TI	L-63	5K
CLAIRE	903	20K

Figure 1: The simple version of the light pen can be constructed according to this schematic. All resistors ¼ W.

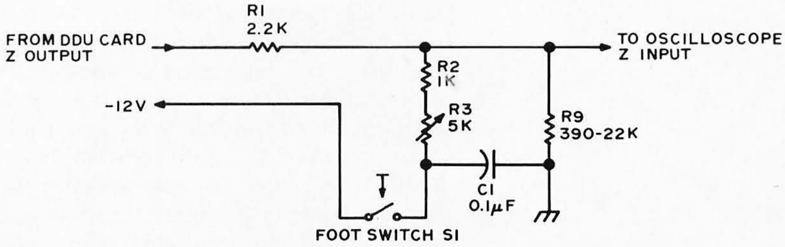


Figure 2: The foot switch control used to flood the screen for "enhance" mode operation is given in this circuit which modifies the Z-axis signal to the oscilloscope driver.

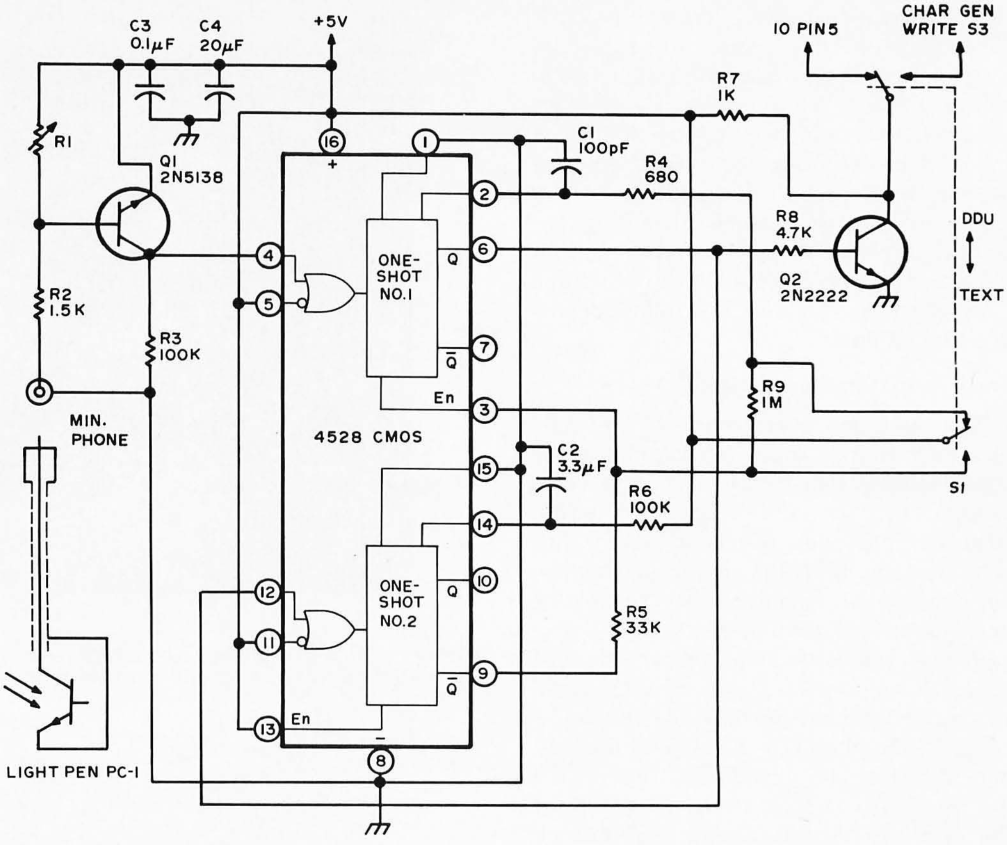


Figure 3: By adding a pair of oneshots to the circuit, the ability to draw pictures is improved through a short data lockout period which avoids smearing.

writing beam reaches that particular dot position. Releasing the footswitch removes the flood and allows the data to be examined.

The circuits just described will probably suffice if you wish to use the light pen only for occasional correction of data. If you plan extensive and detailed work, such as cartooning or statistical data entry, a modification of the circuit will allow you to tailor the light pen's response to your own particular needs and system speed. The circuit shown in figure 3 is similar to the one shown in figure 1. However, it includes two oneshot multivibrators (contained in one CMOS DIP). The first one produces a constant amplitude pulse of approximately 200 nsec duration which is sufficient to bring about the storage of a 1 or 0 bit in most versions of the 2102 memory (ICs 11 to 14 in the oscilloscope graphics interface). The second one delays the generation of another write command for .25 sec, giving the operator sufficient time to withdraw the pen from the screen or move to a new location, before a double or multiple dot can be drawn. Once the two pulses have been timed in accordance with a given system speed and the operator's writing speed, it becomes very easy to draw detailed images with the light pen.

In figure 3 resistor R4 and capacitor C1 control the length of the write pulse, and resistor R5 and capacitor C2 control the wait time. For the 4528 CMOS oneshot, the time of the pulse (T) measured in microseconds is a function of resistance (R) and capacitance (C) measured in ohms and microfarads, respectively, as follows:

T = 2.5 * R * C ** .85;

where a single asterisk denotes multiplication, and a double asterisk exponentiation.

The circuit shown in figure 3 also includes a switch and connections for using the light pen with the author's text display and editing system. Exact details for this connection are not given here, as they will differ with the type and construction of the text display system. I found, however, that the shift register type memories commonly used in these systems require a much longer write pulse than is necessary for the 2102 memories. It was also desired to eliminate the holdoff circuit (second oneshot) for this application. These changes are accomplished with switch S1 and resistors R9 and R5. If these features are not desired, it is recommended that R9 be replaced by a wire, R4 changed to 4.7 kΩ and C1 to 20 pF.

Construction

As is shown in the table accompanying figure 1, several different types of photocells are suitable for use in the light pen. The Texas Instrument (TI) type H-35 or H-38 is a very small device with a built in lens. These were originally designed for use in punched tape and card readers, thus the small size. Their size, sensitivity, and restricted field of view make them ideal for this application. The high impedance of these devices, however, makes them somewhat slow for this application, particularly at low brightness levels. The slow response time limits their use at the faster scan rates, and complicates the smearing mentioned earlier. Another device, the L-63 type which is available from Radio Shack (276-140 infared detector), was found to be considerably faster. Being a much larger device, however, it has a larger field of view, and much of its speed advantage is lost to optical smearing. Models of both photocell types were built and tested by me, with only slight preference for the H-35. With some careful masking, and possibly the addition of a small, short focal length lens (e.g., Edmund Scientific number 12050 cylinder lens, or a small drop of clear epoxy), this photocell will probably perform better than the H-35 for this application. The Claire types 903 and 903-L were tried with only fair results.

Any ball-point pen or felt-tipped marker can be reworked to make a housing for your light pen. Take a tour of the local stationery store to find likely candidates. The L-63 photocell was found to fit nicely into the end of a Graphi-100 marker pen which can easily be disassembled with diagonal cutters. An example of the construction with the L-63 is shown in photo 4, and the H-35 assembly is shown in photo 5.

Secure the photocell in place with epoxy adhesive after attaching the shielded cable. The cable can also be secured against damage from pulling by filling the entire pen with silicone rubber adhesive or ordinary household bathtub caulk. It is wise to keep the cable short, especially with the H-35 or H-38 photocells, to obtain maximum possible response speed. I used an 18 inch (45.7 cm) long miniature coaxial cable leading to a miniature phone plug.

If you are using the simple circuit of figure 1, the parts can be assembled on a small turret terminal board available at most electronic supply houses. This assembly is shown in photo 6. The circuit of figure 3 can be assembled in the same manner with the addition of a 16 pin DIP socket. R4, R5, C1 and C2 should be mounted in such a manner that they can be changed easily (Cambion 601-1512 component clips are useful here).

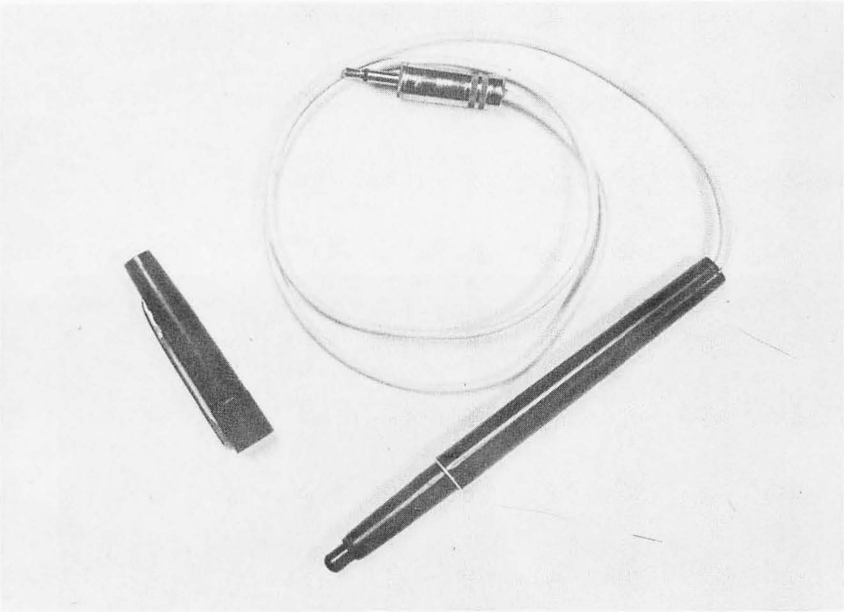


Photo 4: This shows a pen based on the TI type L-63 photocell, built using a marking pen case.

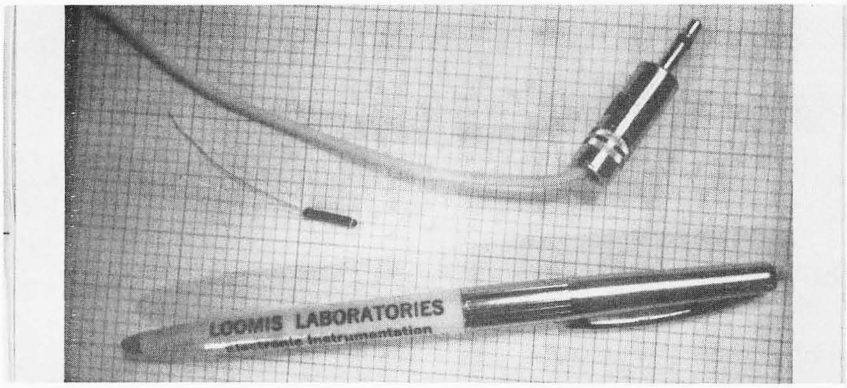


Photo 5: This picture shows an assembled light pen using a TI type H-35 (or H-38) photocell with a standard ballpoint pen housing.

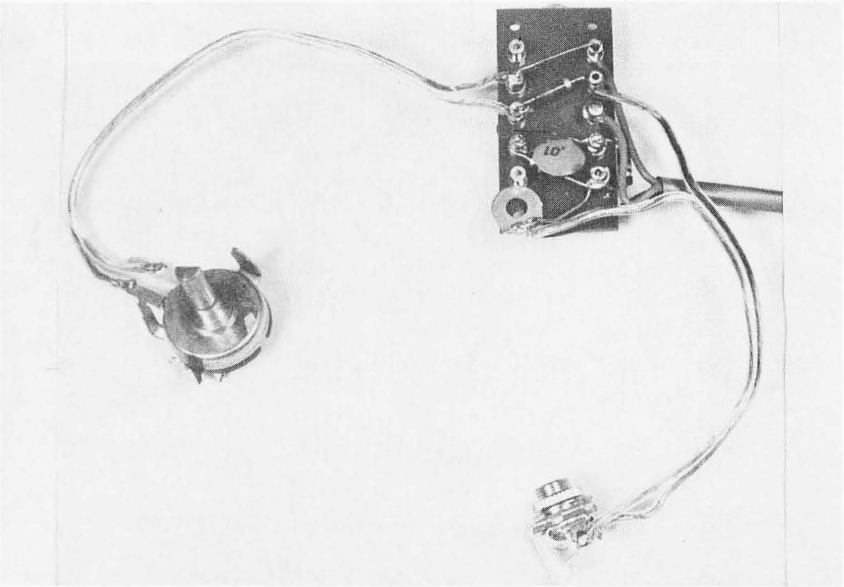


Photo 6: This photo illustrates how the circuit of figure 1 can be assembled using a small turret terminal board. The transistors and R5 are mounted out of sight on the rear side of the board.

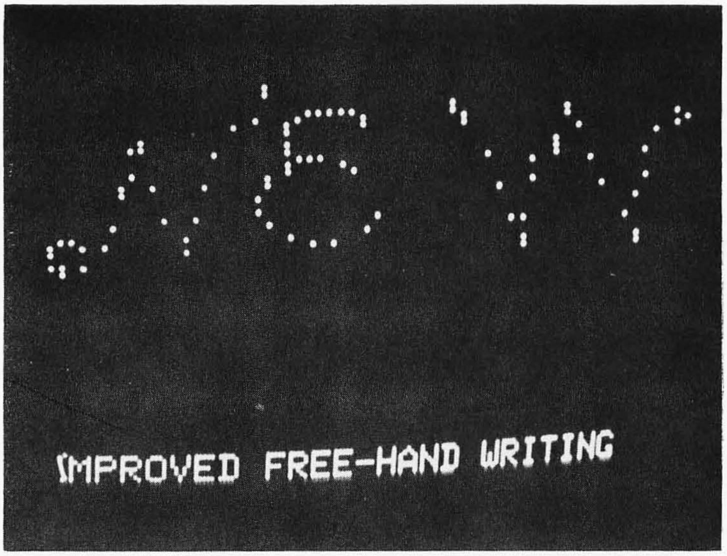


Photo 7: Using the improved circuit of figure 3 reduces much of the over-writing of multiple dots which occurred using the original circuit of figure 1. This is an enhance mode picture.

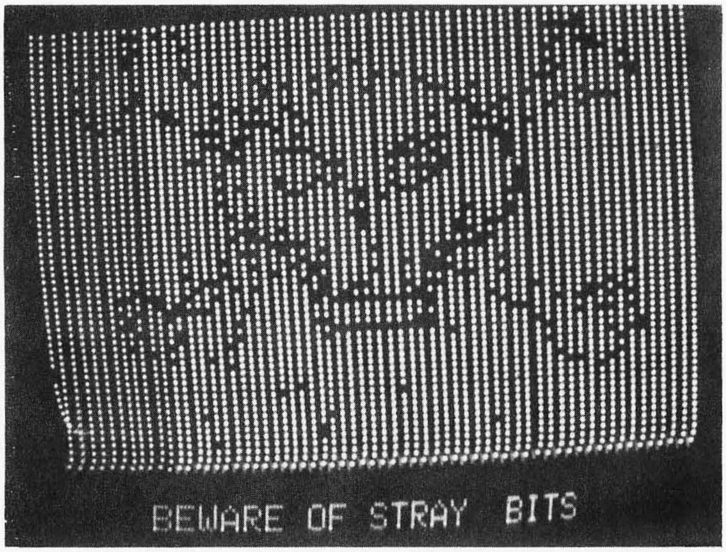


Photo 8: This illustrates a cartoon drawn using the erase mode of operation with the improved circuit of figure 3.

The sensitivity control may be conveniently mounted on the front panel.

The operation of the light pen requires control of the inputs to the oscilloscope graphics unit. I have found that one of the most convenient ways in my system is through a set of manual data switches. This type of input was illustrated as a test fixture for the oscilloscope graphics interface in figure 5 on page 75 of the October 1975 issue of BYTE. In my system, these data input switches are shared with a Mark-8 minicomputer front panel by means of an 8 pole double throw toggle switch. It is also possible to set up input codes to the oscilloscope graphics unit using software in the microcomputer system which drives it.

In order to enter data with the light pen, a deposit switch is pressed whenever the pen is in the proper position for data entry. The deposit switch should be mounted in a convenient location near the display tube and light pen. In my system the light pen deposit switch was mounted next to the original deposit switch of the Mark-8 computer.

Using The Light Pen

To illustrate the use of the light pen, we will cover the procedure necessary to draw a simple figure on the screen in the erase mode using manual controls. Set the switch register to 1000 0110 binary (turn scan on) and depress the deposit switch. This should produce random dots on the screen. Set the switch register for 1000 0010 binary (set Z on) and depress the deposit switch again. The screen will show a full field of dots. (If the Z axis polarity of your display tube is reversed, you will have to use the "set Z off" command (1000 0011 binary) to illuminate the screen.) Set the switch register for 1000 0010 (set Z on), but *do not* activate the deposit switch. Now bring the light pen in contact with the display CRT, and note that the dot or dots within its field of view are erased. To erase the entire screen and start over, simply press the deposit switch and repeat the above procedure.

To write in the enhance mode (screen dark, writing illuminated dots), reverse the above procedure by wiping the screen clean with the "set Z off" command (while the scan is on), and after setting the switch register to "set Z on" without the deposit switch, proceed to write dots with the light pen. In this mode, the flood foot switch must be periodically activated to provide the required illumination. Examples of the light pen's drawing capability can be seen in photos 7 and 8. ■